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Modeling commuting mode choice jointly with work start time and work duration

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A B S T R A C T

This paper presents a joint trivariate discrete–continuous–continuous model for commuters' mode choice, work start time and work duration. The model is designed to capture correlations among random components influencing these decisions. For empirical investigation, the model is estimated using a data set collected in the Greater Toronto Area (GTA) in 2001. Considering the fact that work duration involves medium- to long-term decision making compared to short-term activity scheduling decisions, work duration is considered endogenous to work start time decisions. The empirical model reveals many behavioral details of commuters' mode choice, work start time and duration decisions. The primary objective of the model is to predict workers' work schedules according to mode choice, which is considered a skeletal activity schedule in activity-based travel demand models. However, the empirical model reveals many behavioral details of workers' mode choices and work scheduling. Independent application of the model for travel demand management policy evaluations is also promising, as it provides better value in terms of travel time estimates.

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1. Introduction

Work trips in any urban area are always at the center of focus in urban transportation planning and policy analyses. Work trips in aggregation define peak versus off-peak-period traffic flow in the urban transportation network. Although activity-based modeling practice extends beyond peak-period travel, commuting activities are always at the center of all modeling approaches. The idea behind the concept of skeletal activities in an activity-based travel demand modeling framework is to recognize the importance of work activities in defining urban transportation system performance (Habib and Miller, 2006). Today it is becoming increasingly evident that the once common picture of having very sharp peak-period urban traffic flow within a narrow time window due to the collective work trips is being replaced with a conception of traffic flow which is flatter and distributed over longer time windows (Schwanen and Dijst, 2003). Such a phenomenon is widely known as peak spreading (Mayer and Miller, 2001).

The peak spreading phenomenon is a direct result of workers' mode and trip timing choice decisions. The basic purpose of moving away from a peak-period modeling approach and toward 24-h modeling practice is to capture the peak versus off-peak-period tradeoffs in travelers' travel-related decisions. However, even the 24-h activity-based travel demand models cannot properly capture the peak spreading phenomenon (Roorda et al., 2008). Work activity related decisions are particularly relevant to our daily lives. For this reason, work activities and work trips have received considerable attention in the literature (Bhat and Singh, 2000; Bhat, 2001). Such decisions as work mode choice, departure time, and numbers of stops are typically investigated individually using advanced econometric techniques (Bhat, 1996, 2000). However, dealing with

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work mode choice, start time and duration comprehensively within a unified econometric modeling framework is rare in the literature. It is also worth noting that, in the case of commuting activities, decisions of when to start work, how long to work, what mode to use to reach the work place, etc. are all intricately inter-related (Jara-Diaz, 2003a,b).

From the methodological point of view, most of the advanced techniques available in the literature require discretization of time in some manner (Bhat, 2001; Bhat and Steed, 2002). In such cases, developing the modeling structure always remains at the discretion of the researcher based on the manner in which time is to be discretized. A comprehensive methodological approach is necessary in order to address interrelationships between commuting mode choice, work start time, and work duration. It is necessary to develop a modeling framework that allows the modelers to avoid any arbitrary discretization of time for trip timing decisions. Such an approach can address realistically the peak spreading phenomenon in urban transportation networks while simultaneously facilitating the evaluation of a wide range of alternative policy options in order to reduce peak-period traffic congestion.

Unlike the conventional four-stage model, activity-based travel demand models consider interrelationships of different activity decisions (mode, start time, duration etc.) at the disaggregate level. The typical approach to introducing such interrelationships involves the use of joint probability distributions of the decisions. Still, many operational activity-based models have difficulties with introducing policy sensitivity to the distributions of the decisions that serve as key inputs to the activity schedulers. In TASHA, FAMOS, and ALBATROS for example, base year distributions cross-classified by activity type, person, household, and schedule attributes are used in a decision tree approach or are randomly drawn from observed distributions in order to simulate activity frequencies, start times, and durations for the population (Roorda et al., 2008; Pendyala et al., 2005; Arentze and Timmermans, 2004). Such approaches are insufficient when considering policies and scenarios that have the potential to significantly shift travel trends away from the base year distribution of activity start times. CEMDEP, the econometric modeling system for activity-travel demand, uses econometric models for almost all decisions related to activity-travel demand.

Even in this case the individual econometric models for mode choice, start time, durations, etc. are univariate in nature and thus the approach fails to address the interrelationships between all of these decisions at the estimation stage (Bhat et al., 2004). The activity-based models described by Vovsha and Bradley (2004), on the other hand, are examples of models that include explicit tour-based time-of-day discrete choice models to schedule the travel tours of individuals. Although this approach represents a significant improvement over the use of base year distributions or individual univariate econometric models, limitations remain with in terms of the representation of time as a discrete value. Efforts have been made to incorporate the interrelationship between mode choices and start time of work activity using joint discrete–continuous modeling, but work duration has still been considered as exogenous input to the model (Habib et al., 2009). On the other hand Munizaga et al. (2006) modeled mode choice and duration of work activity jointly, but without considering start time.

The importance of work duration in travel demand is well argued in the literature (Jara-Diaz, 2002, 2003a,b). We earn money by spending time in work activities, whereas we typically spend money by participating in other activities. The worker's work duration is part of a medium- to long-term decision process in contrast to the daily activity scheduling decisions of mode choice, start time, etc. This is a fundamental reality in household-based decision dynamics (Miller, 2005). It is for this reason that work duration should be considered as endogenous to daily activity scheduling decisions, a factor which is figured in by considering work schedule as a skeletal schedule in activity-based travel demand modeling (Roorda et al., 2008). When to start work and which mode to choose are obviously conditional to how long a worker plans to work. However, obviously there are daily adjustments in work start time, work duration, and commuting mode choice decisions also. It is for this reason that an investigation of joint mode choice, work start time, and work duration must consider systematic and random factors influencing these three decisions. At the same time, in order to be consistent with a theoretical understanding of decision dynamics, work duration should be endogenous to the other decisions in the investigation. Research on joint multiple decision modeling has been reported on in the literature (Bhat, 1998a; Munizaga et al., 2008), but investigations of joint mode choice start time and duration of commuters' work activities have been rare. From the practical policy analysis and activity-based travel demand modeling perspective, any effort to model commuters' mode choice, work start time, and duration is crucial.

In this paper, a modeling approach for joint commuting mode choice, work start time, and work duration is developed. The econometric formulation of the presented model ensures correlations among these three decisions and allows for the use of a continuous time modeling approach for start time and duration. In addition, work duration is considered as an endogenous variable in work start time choice. However, this modeling structure can be applied for any discrete–continuous–continuous decision situation. The desirable property of the model is that the likelihood function is of closed form and can be estimated using the conventional maximum likelihood estimation technique. However, the primary contribution of this paper is twofold in nature. Methodologically, it presents a robust structure of dealing endogenous work duration into joint mode choice and start time choice models with continuous hazard specifications for start time and duration. For policy application, it has the potential to test a wide range of travel demand management policies, where policy responses can be expected to affect the tradeoffs between commuting mode choice, work start time and work duration in a continuous time scale. For empirical investigation, the model is estimated using a data set collected in the Greater Toronto Area (GTA).

The next section of this paper presents the econometric structure of the joint model. Section 3 discusses the data source for empirical investigation. Section 4 discusses the empirical model. The final section summarizes important findings from the research.

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